

Non-Chloride Deicing Compounds - SHORT

Below is a summary of information from 15 different sources, mostly technical in nature. This version represents the shorter version of this summary. An accompanying document follows the same structure but includes more detailed information. While this summary was intended to look at “emerging” deicing compounds, this review of all non-chloride deicers highlighted that many of the compounds researched through the 90s and early 2000s are not understood at the same level as Sodium Chloride (NaCl). Therefore, the focus of this summary is on non-chloride deicers

Preliminary thoughts – Things to consider and developing recommendations

- Thoughts to consider:
 - Chloride (Cl) is not the only ion of concern, Sodium (Na) is too
 - Some studies show toxicity of Potassium (K) to macroinvertebrates¹
 - In water, Calcium (Ca) and Magnesium (Mg) have the least impact²
 - Many “alternatives” include these cations.
 - Challenges with existing research
 - Many compounds not researched well, with many studies showing different results.
 - There are evolving manufacturing processes that affect the purity of materials.
 - All known deicers once applied, dissolve and are transported in one way or another to surface water or groundwater without significant removal in stormwater BMPs
 - Non-chloride deicers generally don’t persist long, but may have short-term impact on Biological Oxygen Demand (BOD).
 - However, biological activity in winter months is depressed and the re-aeration rate of water is higher at winter temperatures, possibly diminishing the impact of the high BOD.
 - Byproducts (e.g., pickle brine, cheese brine, agricultural byproducts) have variable composition and are subject to regional availability.
 - Byproduct brines need the same NaCl content to be effective, so no reduction in NaCl³
- Developing Recommendations:
 - Consider how easy it is to adopt product:
 - Do they work in the existing equipment?
 - What kind of training is needed?
 - What kind of personal protective equipment is needed?
 - Consider products for mid-latitudes that:
 - Stick around through traffic and rain
 - Work best at mild temperatures
 - Provide recommendations for piloting mixtures or alternative compounds for particular weather patterns/circumstances
 - The most strategic use of deicers is to use a selection of products that will meet your needs and reduce the total volume of deicer, abrasive or additives needed.
 - The benefit of each deicer seems to be maximized in mixtures. However due to the increased complexity of using mixtures, each mixture should be well studied before scaling up in operations.
- Additional information related to all deicing compounds (including chloride deicers)
 - Dyes are added for a number of reasons, but can show that an area has been treated. Impacts from dyes are unknown and represent an area for more research
 - Anti-caking agents can increase toxicity due to cyanide content, but direct evidence is limited. Products

¹ <http://www.the-aps.org/mm/hp/Audiences/Public-Press/2018/71.html>

² <http://onlinepubs.trb.org/Onlinepubs/sr/sr185/185-043.pdf>

³ <https://docs.lib.purdue.edu/mwg-internal/de5fs23hu73ds/progress?id=NeQ3SCEYVQ22Nosf-bA1rIZxP6BtF3-bRYm-HoAd1hA,&dl>

Products

- From Minnesota Local Road Research Board 2014 Report and summarized on **SaMS IP NonCl Deicer MinnesotaSummary.xlsx**. Information provided below is in addition to what is summarized on the spreadsheet. The products in this group include Acetates, Formates, Glycerol/Glycol, Succinates, and Beet Juice⁴
 - Acetates
 - Found to significantly damage asphalt pavements.⁵
 - Calcium Magnesium Acetate⁶
 - Is said to take 15-30 minutes longer to induce melting than NaCl
 - Effectiveness is limited in different precipitation types and lower temperatures
 - Residual CMA can last on roads for up to 2 weeks
 - When wet can clog spreading equipment/stick to truck beds
 - Low toxicity
 - High price (\$650-675/ton)
 - Formates
 - Includes Apogee – Sodium Formate
 - \$3/gallon including transportation costs
 - Found to significantly damage asphalt pavements.⁷
 - Glycerol/Glycol
 - Potential human carcinogen⁸
 - Succinates⁹
 - Potassium Succinate (KSu) outperformed other succinate salts
 - Reduces corrosion to steel when blended with salt brine (best at 2%)
 - Minimal to no concrete scaling
 - Cost about \$2.50/gallon
 - Should not be used below 23°F
 - Similar performance to NaCl with regards to friction
 - Beet Juice
 - National Geographic Article¹⁰
 - Can be mixed with salt to help it stick to surfaces
 - Can clog machinery used to spread as a brine or a treated salt
 - Sugar in the solution lowers the freezing point, allowing it to deice below NaCl's 15°F limit
 - 2018 American Physiological Society Press Release¹¹
 - Contains about 12% NaCl
 - Can coat the road for up to 1 week
 - Can attract wildlife to the road (sweet taste)
 - Has an anti-corrosion property
 - Higher cost than NaCl

⁴ <https://lrrb.org/media/reports/TRS1411.pdf>

⁵ <https://www.codot.gov/programs/research/pdfs/2009/antiicing.pdf>

⁶ https://www.michigan.gov/documents/ch2-deice_51438_7.pdf

⁷ <https://www.codot.gov/programs/research/pdfs/2009/antiicing.pdf>

⁸ https://www.michigan.gov/documents/ch2-deice_51438_7.pdf

⁹ <https://trid.trb.org/view/1508221>

¹⁰ <https://news.nationalgeographic.com/news/2014/02/140204-melt-snow-ice-salt-beet-juice-pickle-brine/>

¹¹ <http://www.the-aps.org/mm/hp/Audiences/Public-Press/2018/71.html>

- High BOD
 - Additional stress on Mayflies
- Products not from Minnesota Local Road Research Board 2014 Report (i.e., not on the SaMS_IP_NonCl_Deicer_MinnesotaSummary.xlsx)
 - Non-Chloride Agricultural Products
 - A report titled, “Developing Locally Sourced Brine Additive for Anti-Icing” outlined a process for identifying potential deicers from waste material¹²
 1. Identify potential waste material or by-product (e.g., free of contaminants)
 2. Design experiment to determine concentrations
 3. Determine ice melting performance, corrosion to steel, and impacts to concrete
 - May be worth adding impacts to the environment here
 4. Field operational testing of highest performers
 5. Implementation to maintenance agencies
 - Distillery brine
 - Favorable results as an anti-icer mixed with other compounds to reduce corrosivity and function at temperatures below those where NaCl and MgCl₂ brines work.¹³
 - The composition of a distillery byproduct pre-wetting agent varies from batch to batch and over time, and overall did not perform in a beneficial way as a pre-wetting agent.¹⁴
 - Pickle Brine & Cheese Brine
 - Pickle Brine
 - Still need 23.3% NaCl content¹⁵
 - Some testing has shown that the salinity can vary and pH levels could damage equipment¹⁶
 - Cheese Brine
 - Still need 23.3% NaCl content¹⁷
 - National Geographic Article¹⁸
 - “Stinky” odor
 - Cheese brine freezes at -21°F not -6°F like NaCl brine
 - Organics (from Transportation Research Board’s: 1980 Alternative Highway Deicing Chemicals)¹⁹
 - Methanol:
 - Works well below temperatures experienced in the mid-Atlantic.
 - It has a neutral pH and is noncorrosive
 - Volatile, although volatility is reduced at snow and ice temperatures
 - Flammable but at temperatures above freezing
 - Methanol has been ruled out of use in Michigan because²⁰:
 - Turns into a gas quickly and must be reapplied more often than salt
 - Breakdown products of methanol can contribute to ozone pollution in the lower atmosphere
 - Protective wear necessary

¹² <https://pdfs.semanticscholar.org/dc7d/b590bba5eec847a379a71dc670bc0a9152ce.pdf>

¹³ <https://pdfs.semanticscholar.org/dc7d/b590bba5eec847a379a71dc670bc0a9152ce.pdf>

¹⁴ http://www.virginiadot.org/vtrc/main/online_reports/pdf/00-r12%20.pdf

¹⁵ <https://docs.lib.purdue.edu/mwg-internal/de5fs23hu73ds/progress?id=NeQ3SCEYVQ22Nosf-bA1rIZxP6BtF3-bRYm-HoAd1hA,&dl>

¹⁶ <https://mntransportationresearch.org/2018/08/01/carver-county-evaluates-pickle-brine-for-ice-control/>

¹⁷ <https://docs.lib.purdue.edu/mwg-internal/de5fs23hu73ds/progress?id=NeQ3SCEYVQ22Nosf-bA1rIZxP6BtF3-bRYm-HoAd1hA,&dl>

¹⁸ <https://news.nationalgeographic.com/news/2014/02/140204-melt-snow-ice-salt-beet-juice-pickle-brine/>

¹⁹ <http://onlinepubs.trb.org/Onlinepubs/sr/sr185/185-043.pdf>

²⁰ https://www.michigan.gov/documents/ch2-deice_51438_7.pdf

- Specialized application equipment is required
 - Cost is 5.5 times that of NaCl
- Ethanol and Isopropanol
 - Many similar properties as Methanol
 - Ethanol is the least toxic of all 3 alcohols, however it's reaction with chlorine in water supplies can produce chloroform (implication for runoff into source waters)
 - Vapor density much greater than air (will stick around a while)
 - Each is 3 times the cost of methanol
- Acetone
 - Similar to the 3 alcohols, but more flammable and more expensive.
- Formamide
 - Contains nitrogen, so it is not allowed to be used in Virginia
- Dimethyl Sulfoxide (DMSO)
 - Favorable in some senses
 - Relatively low toxicity
 - Very high solubilization and penetration properties leading to its ability to pick up and mobilize other pollutants
- Verglimit²¹
 - Patented bituminous concrete pavement that contains calcium chloride pellets encapsulated in linseed oil and caustic soda. As the pavement wears, the surface becomes very difficult for ice or packed snow to adhere.
 - Does not melt much snow after snowfall but prevents ice and snow from binding to the road surface.
- Sodium propionate²²
 - "SP was found to conform to the standard for toxic substances of deicer in Japan, to achieve more rapid deicing than sodium chloride (NaCl), and to cause almost no corrosion of metal. To reduce costs while taking advantage of SP, the mixing of NaCl and SP, which exhibits performances intermediate between those of NaCl and SP, is considered to be a solution. A mixture of 80% NaCl and 20% SP shows freezing point and ice melting performance equivalent to those of NaCl, mitigates the concentration of chloride ions and the inhibitory effects of NaCl on plants, and is still 80% less corrosive to metal than NaCl is. Considering SP's high solubility in water and the field test results, it is recommended that SP be used as a pre-wetting material."
 - This is the only identified deicing use of this food preservative that is toxic to mold and some species of bacteria.

²¹ https://www.michigan.gov/documents/ch2-deice_51438_7.pdf

²² <https://trid.trb.org/view/1437472>